Computer Networks

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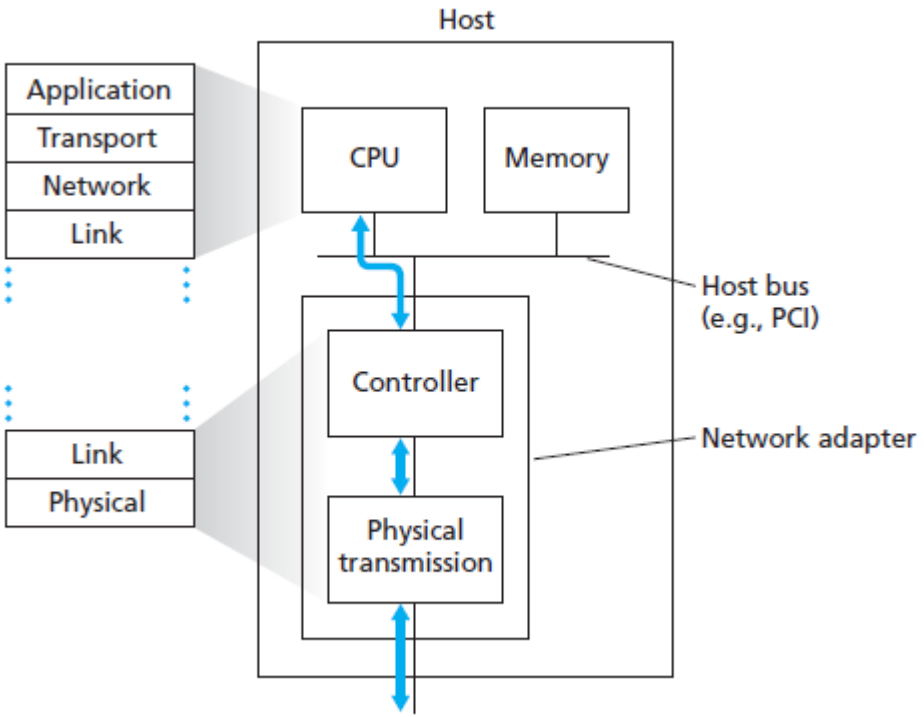
Data Link Layer

Data Link Control Protocols

- We shift our emphasis to that of sending data over a data communications link
- To manage exchange of data over a link
  1. Services Provided to the Network Layer (Connection Control)
  2. Framing
  3. Flow control
  4. Error control
  5. Link Access - Media access control (MAC)

Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC)
  - Ethernet card, 802.11 card etc.
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware software, firmware



Connection Control

Connection Control

- **Unacknowledged Connectionless** Service
- **Acknowledged Connectionless** Service
- **Acknowledged Connection-oriented** Service
  - Connection establishment
  - Data transfer
  - Disconnection

Connection Control

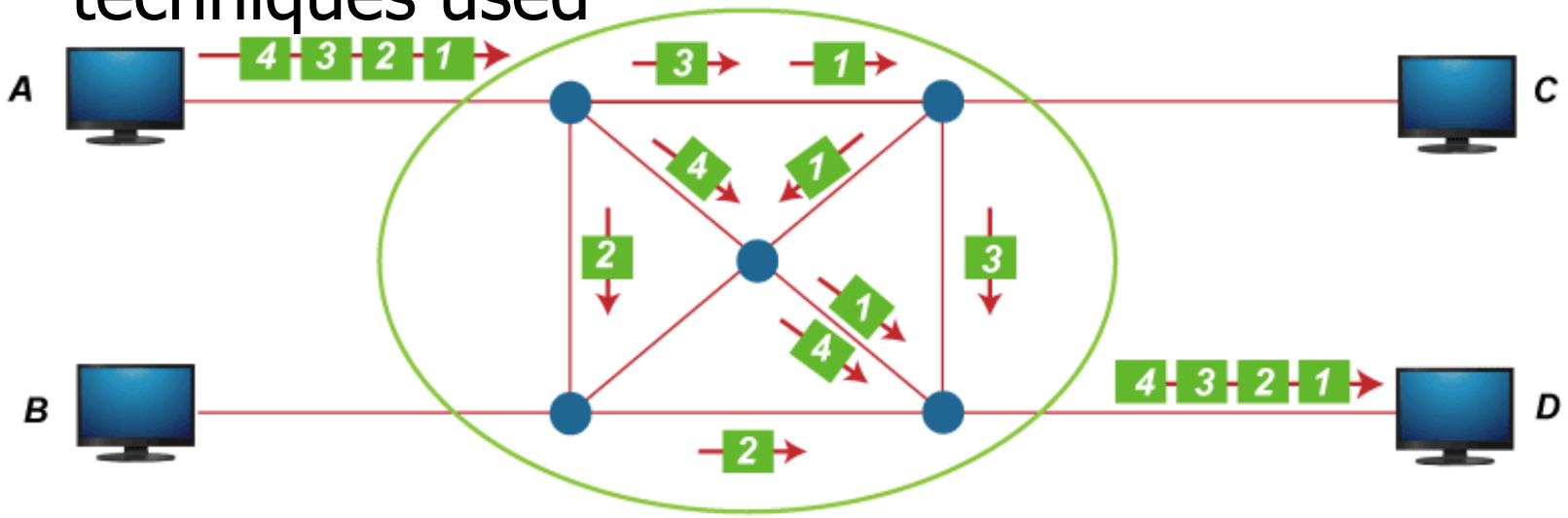
- **Unacknowledged connectionless service**
  - —No connection required and without acknowledgement for data frames
  - —Appropriate for
    - —low error rate
    - —Reliable
    - —and real-time traffic
  - —Error recovery is up to higher layer
  - —Ethernet and User Datagram Protocol (UDP) are good examples.

Connection Control

- **Acknowledged connectionless service**
  - —No connection required but each frame is individually acknowledged
  - —Useful for unreliable channel, such as wireless systems.
  - —For Example, 802.11 (WiFi)

Packet Switching Network

- The message is divided into packets.
- Each packet contains a header which includes the source address, destination address, and control information.
- Store and Forward (cause delay) and routing techniques used



Packet Switched Network

Connection Control

- **Acknowledged connection-oriented service**
  - —Guarantee error-free and in sequence delivery of data frames
  - —Consists of **three phases**
    - Connection set up (variables and buffers initialization)
    - Data frame transmission
    - Connection termination (release variable and buffers)
  - TCP is an example

Connection establishment

- Before transmitting data in connection oriented, the sending device has to determine the availability of resources and the other device to exchange data and a connection has to be established by which data can be sent.
- First sender sends a connection request packet to the intended receiver.
- After that, the receiver returns a confirmation packet to the requesting computer.
- Finally, the sender computer returns a packet acknowledging the confirmation.

Data Transfer & Connection Release

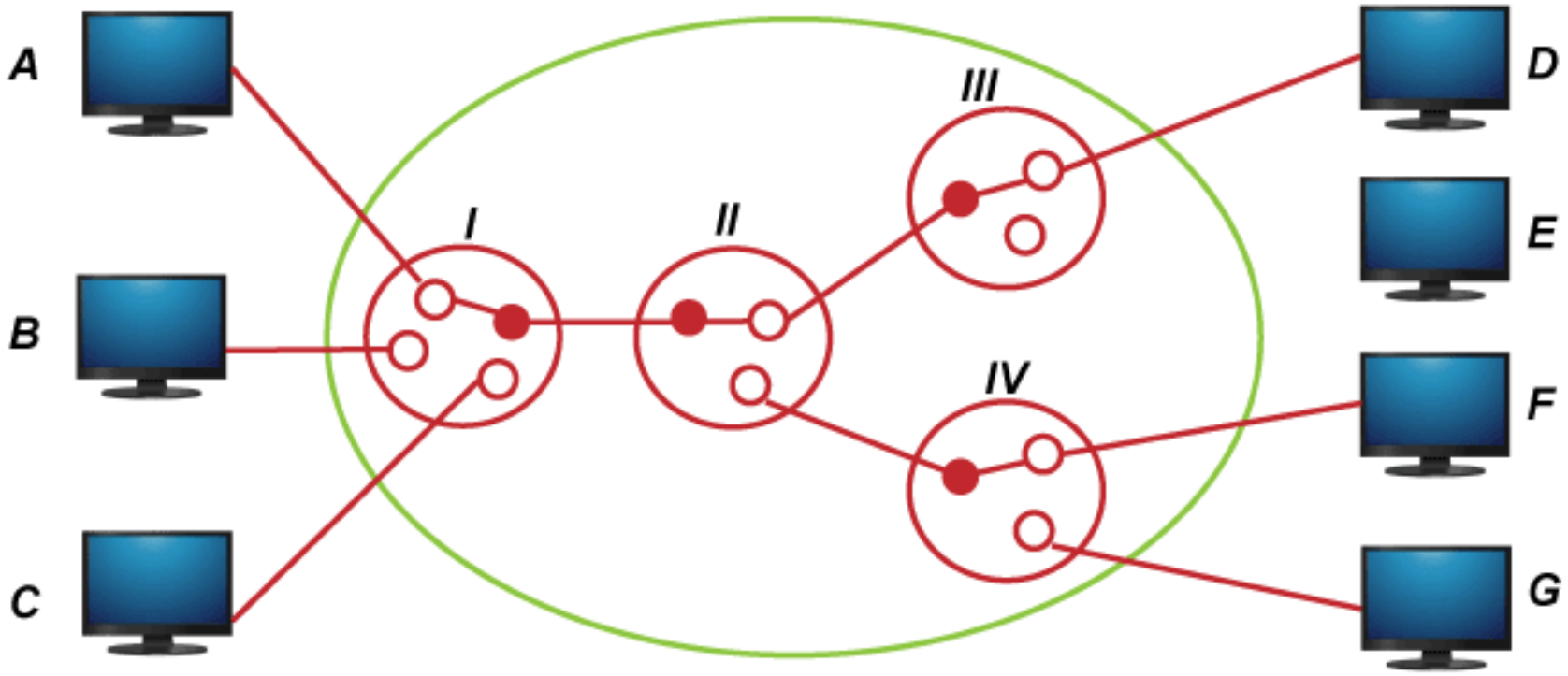
- **Data Transfer**
  - The sender starts sending data packets to the receiver.
- **Connection Termination**
  - The connection termination also requires a three-way handshake.
  - First, the sender sends a disconnection request packet.
  - After that, the receiver confirms the disconnection request.
  - Finally, the sender returns a packet acknowledging the confirmation.

Connection Oriented Networks

- **1. Circuit-Switched Network**
  - Circuit-switching networks are generally known as connection-oriented networks.
  - In this, a dedicated route is being established among sender and receiver, and whole data or message is sent through it.
  - A dedicated physical route or a path or a circuit is established which last for the duration of the connection.
  - Public Switched Telephone Network (PSTN)
  - Work at Physical Layer

Connection Oriented Networks

- **Circuit-Switched Network**



Circuit Switched Network

Bell System switchboard in 1943

Is GSM circuit-switched?

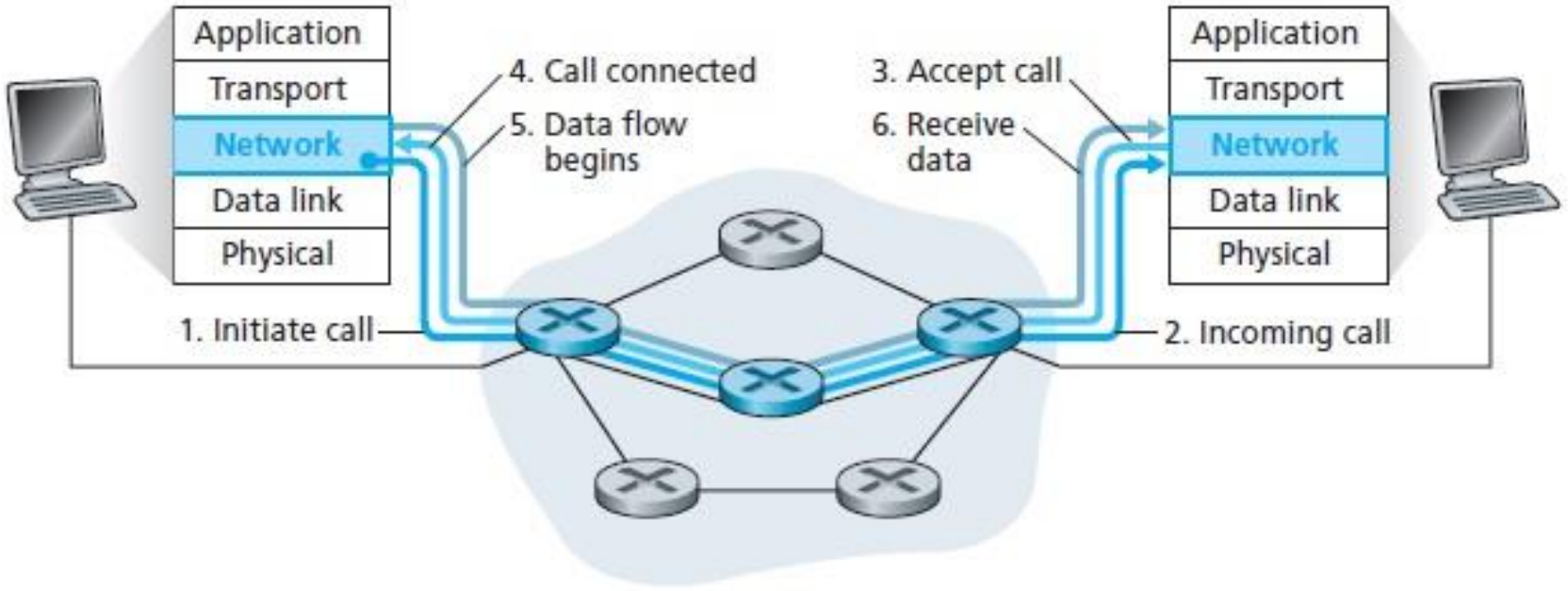
- In the cellular network GSM (2G) and UMTS (3G) use circuit switching for voice, and use packet switching for GPRS data traffic.
- In LTE (4G) the entire network uses packet switching and has no capability for circuit switched network support.
- Voice over IP is a telephony protocol that uses packet switching.

Connection Oriented Networks

- **2. Virtual Circuit-Switched Networks**
  - In Virtual Circuit-Switched networks, a preplanned route or path is established before data or messages are transferred or sent.
  - The message is transferred over this network is such a way that it seems to user that there is a dedicated route or path from source or sender to destination or receiver.
  - For example, X.25 and Frame Relay Networks

Connection Oriented Networks

- **Virtual Circuit-Switched Networks**



Comparison

- The route followed by packets
- Availability of Bandwidth
- Wastage of Bandwidth
- Connection setup
- Congestion
- Reliability

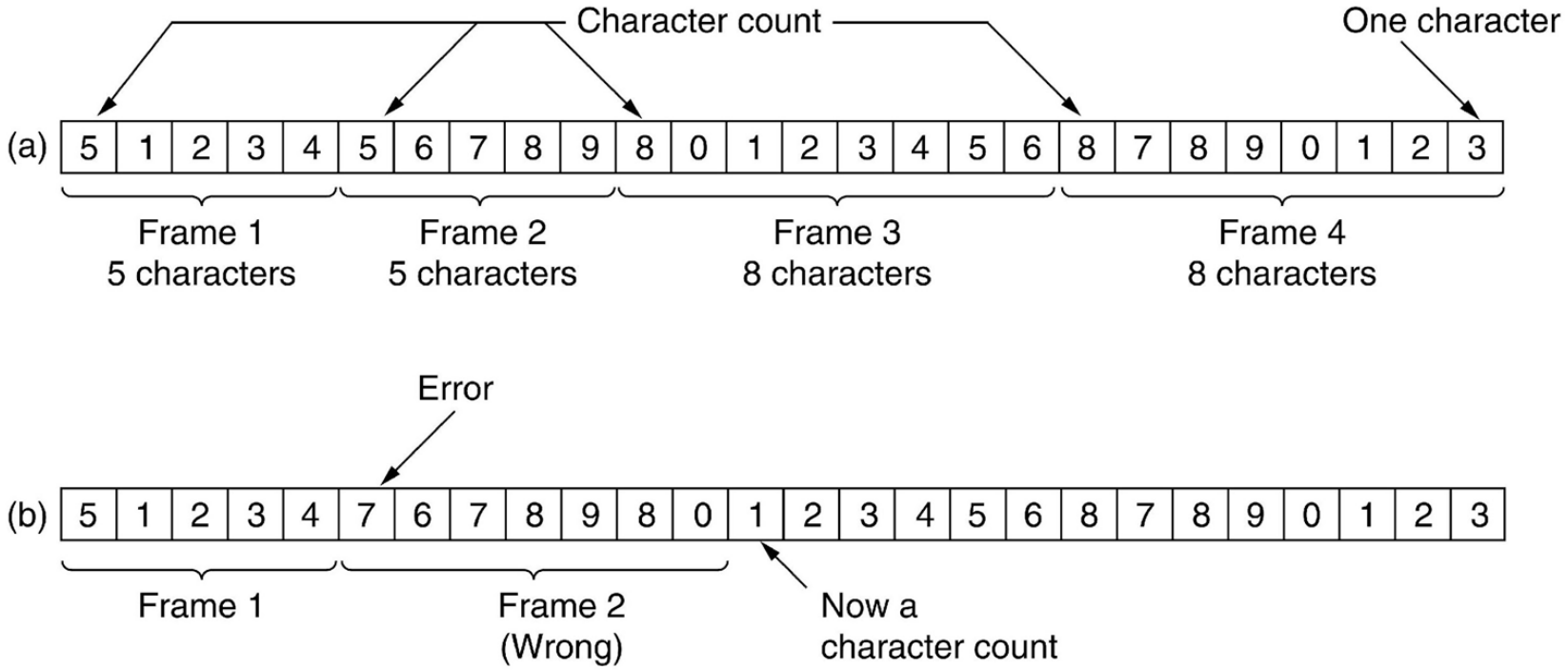
Framing

What is Framing?

- Since the physical layer merely accepts and transmits a stream of bits without any regard to meaning or structure, it is up to the data link layer to create and recognize frame boundaries.
- encapsulate datagram into frame, adding header
- This can be accomplished by attaching special bit patterns to the beginning and end of the frame.
- If these bit patterns can accidentally occur in data, special care must be taken to make sure these patterns are not incorrectly interpreted as frame delimiters.

Framing - Character Count

- This method uses a field in the header to specify the number of characters in the frame and hence a node knows how many characters follow, and hence where the end of the frame is.

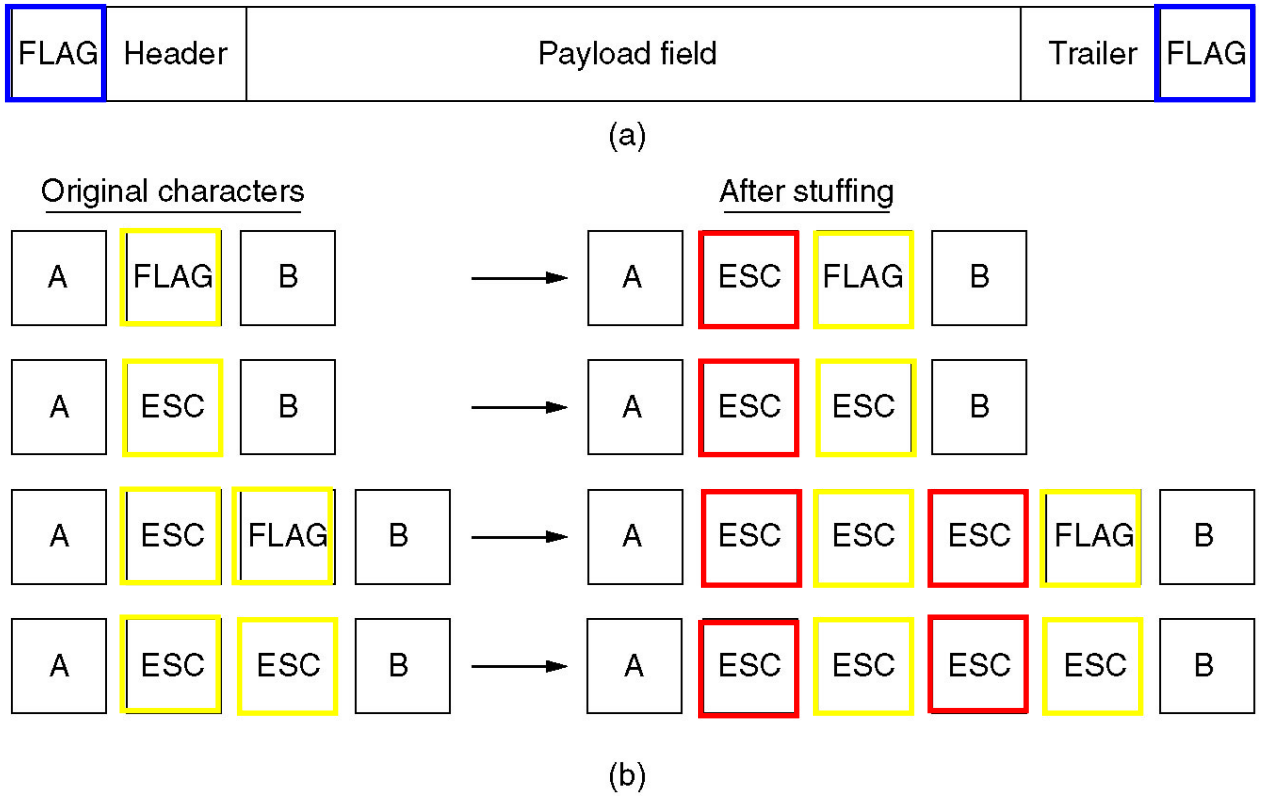


(a) Without errors. (b) With one error.

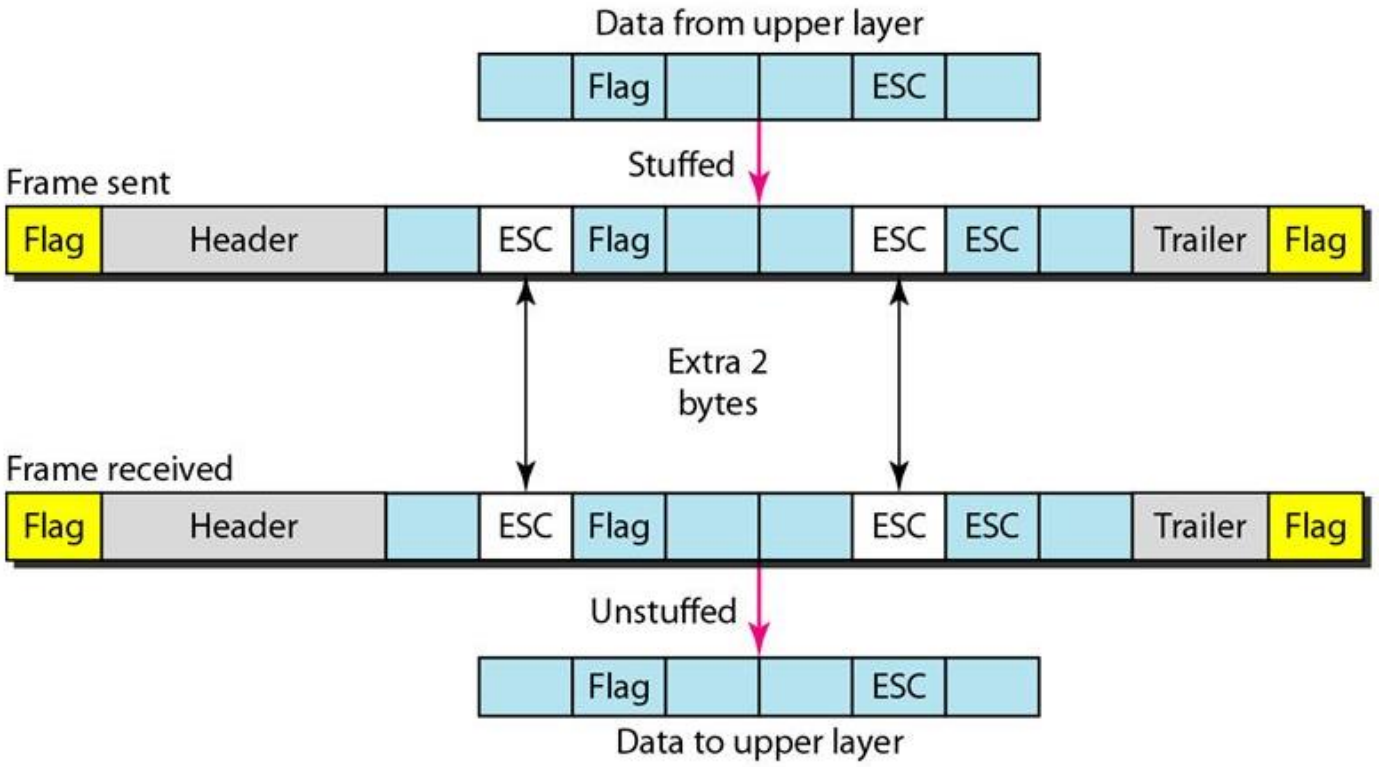
Framing - Character Stuffing

- Each frame starts with special start and end bytes (Flag Bytes).
- But here we have to prevent frame boundary (Flag Bytes) from appearing at the data content by character stuffing.
- **Character Stuffing:** inserting ESC ahead of accidental flag byte within the data content.
- After error, can always find start of next frame.

Framing - Character Stuffing



Framing - Character Stuffing



Byte stuffing is the process of adding 1 extra byte (ESC) whenever there is a flag or escape character in the text.

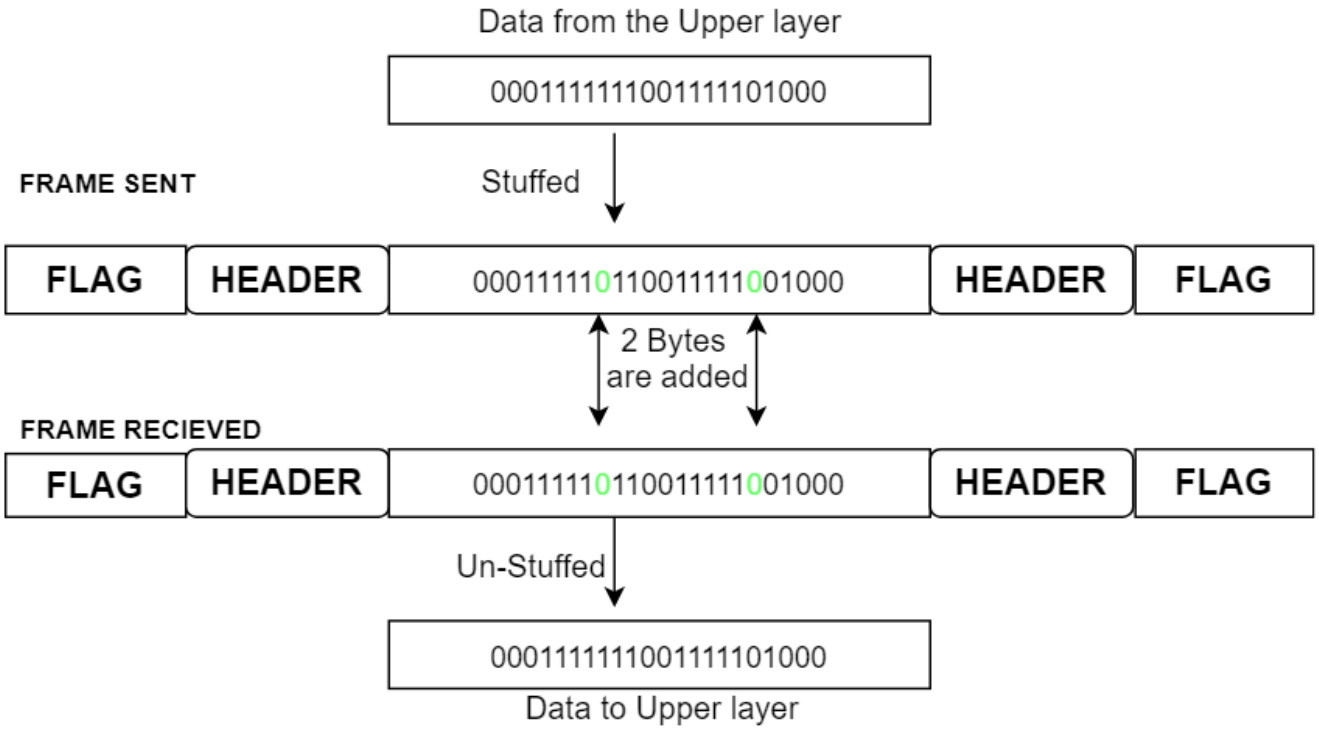
Framing - Character Stuffing

- If ESC byte gets corrupted by noise. Detect pre-mature end-of-frame.
- Or FLAG byte gets corrupted and frame runs on too long.
- Can still find next frame by looking for next FLAG. At most lose 1 or 2 frames.

Framing - Bit Stuffing

- The third method allows data frames to contain an arbitrary number of bits and allows character codes with an arbitrary number of bits per character.
- Each frame begins and ends with bit pattern 111111 (6 1’s)
- Prevent a flag from appearing in data by bit stuffing.
- If 5 1's in a row in data, stuff a 0 in so will never be 6 in a row.

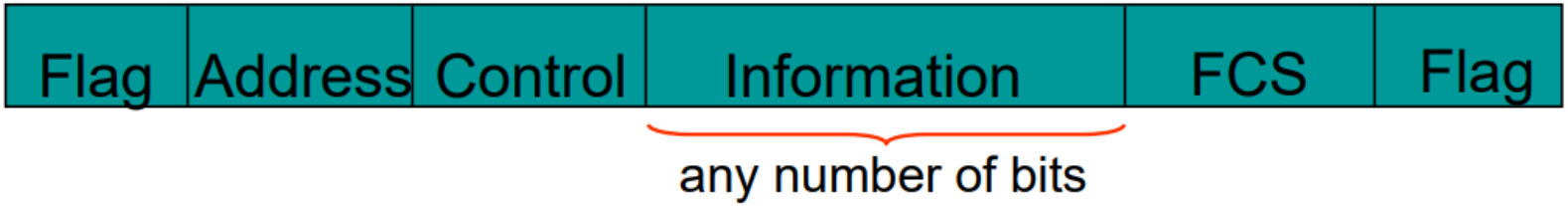
Framing - Bit Stuffing



- (a) Original data.
  (b) Stuffed data transmitted.
  (c) De-stuffed data received.

Framing - Bit Stuffing

HDLC frame



- Frame delineated by flag character
- HDLC uses *bit stuffing* to prevent occurrence of flag 01111110 inside the frame
- Transmitter inserts extra 0 after each consecutive five 1s *inside* the frame
- Receiver checks for five consecutive 1s
  - if next bit = 0, it is removed
  - if next two bits are 10, then flag is detected
  - If next two bits are 11, then frame has errors